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The Impact of Group versus Individual Housing of the Performance of Karadi Calves in Sulaymaniyah Governorate Prior to Weaning

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Abstract

Early housing arrangements have a significant impact on the wellbeing, health, and development of dairy calves. There is little information on how native Karadi calves in Iraq's Kurdistan Region react to various home configurations. The performance, health, behavior, and hematological parameters of Karadi dairy calves were assessed in this study in relation to individual, pair, and group housing from birth to 18 weeks of age. The study, which involved fifteen females newborn Karadi calves, was carried out at the University of Sulaimani, College of Agricultural Engineering Sciences, Animal Science Farm during February and June 2025. Three housing treatments were randomly allocated to the calves: group, pair, and individual housing. Weekly measurements of body weight and withers height were made, clinical health factors were routinely noted, and monthly blood samples were taken to evaluate immunological and hematological markers. With treatment as fixed factor, the data were examined using least squares ANOVA. According to the results, there were no significant differences in body weight and withers height between the treatments throughout the preweaning phase. On the other hand, group-housed calves showed a significantly greater body weight compared individually-housed calves starting at week 11. In later development stages, pair housing produced the tallest withers. With relatively brief variations in fecal scores, clinical health markers were largely low during all treatments, indicating good general health condition. According to hematological research, pair housing was linked to increased counts of monocytes, granulocytes, lymphocytes, and total white blood cells at many time periods, indicating improved immunological response in both individual and group housing.

Keywords: ***Karadi calves, individual housing, pair housing, group housing, calf welfare, growth performance, behavior***

I. Introduction

Cattle breeds are important agricultural animals in the Kurdistan Region of Iraq and other areas of the world because of their high economic value (Saeed *et al*., 2022). The primary native cattle breeds in Iraq are the Jenubi, Kurdi, Sharabi, and Rustaqi. A number of commercial crossbreeds, including Hereford and Jersey and Holstein-Friesian, have been introduced over time (Alshawi *et al.*, 2019). The most common breed in Iraqi Kurdistan is the Karadi cow, which is mostly raised for meat. They have horns on both sexes, are petite, brown to black in hue, and have short body hair that grows into long hair early in life. Only animals grown on a single state farm have been used to gather data about the performance of this breed (Ahmed *et al*., 2010; AlKudsi and Elia, 2010). The health and performance of dairy calves have been demonstrated to be impacted by various housing arrangements, such as group vs individual living. Some studies found that living in a community increased weight more than living alone (Jensen *et al*., 2015). During the preweaning stage, group living may improve the welfare of individual dairy calves (Costa *et al.*, 2016). To assess the possible immediate and long-term effects of this housing strategy on calves' performance and welfare indicators, further information is needed (Costa *et al*., 2016).

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Social learning has been suggested as a means of influencing feeding behavior, and this greater initial consumption is likely the cause of this improved growth when compared to calves housed in separate housing (de Paula Vieira *et al*., 2012; Miller-Cushon and DeVries, 2016). The health of calves in pair housing has generally been confirmed to be comparable to the health of individually housed calves during the preweaning period (Jensen and Larsen, 2014; Bolt *et al.*, 2017). It has also been shown that pair housing improves the emotional state (mind) of calves, improving their social and cognitive abilities, as compared to calves reared alone. Calves housed in pairs, for example, learned a task faster (Gaillard *et al*., 2014; Meagher *et al.*, 2015), which may have a major impact on behavioral flexibility in later life. Evaluating the effects of different therapies on a calf's natural behavior is more difficult, especially if the calf is maintained in captivity. However, laying time has been suggested as an indicator of ruminant well-being (Mattiello *et al.*, 2019). Claiming that prolonged laying periods for calves might be a sign of better health, especially during critical periods like grouping during weaning. Pair housing has been shown to lengthen laying times during the weaning and postweaning stages when compared to calves housed individually (Liu *et al*., 2019).

This study's goal was to evaluate how dairy Karadi calf's performance and welfare were affected by individual, paired, and group housing during the preweaning phase, also to assess the effects of individual, pair, and group housing during the preweaning stage using a welfare framework by analyzing the Karadi calf's body (weight growth, withers height, health parameter and hematological test) from birth to 18 weeks of age.

II. Materials and Methods

Ethics Approval

Experimental animal: all applicable national and international regarding the use and care of animals were adhered to.

Animal's care and experimental design

This study was conducted in the Animal Science Farm, College of Agricultural Engineering Sciences, University of Sulaimani, from February to June 2025, by using 15 female newborns local Karadi calves, directly after birth until 18 weeks of age. During the experimental period, all of the Karadi calves were moved to the calf unit and housed in separate pens (1.2 x 1.2 m) with bedding on the solid floor with wood shavings, and new bedding was added daily. The calves were bottle-fed after being taken from their dam on study day 0. A salt block with macro- and micro minerals (Se, Zn, Cu, Mn) was available for the animals during the experiment, the calves were ear tagged for identification purpose.

Treatments

Before starting the experiment, the colostrum was gathered from the Karadi farm, which is close to Sulaimani. All of the individual samples were combined in a large container to create a pooled colostrum, which was then stored in brand-new, separate 2-liter bottles of polyethene and frozen at -20°C until it was needed. Colostrum quality on farms was first categorized using a brix refractometer. Calves were administered pasteurized milk twice daily at 8:00 am and 5:00 pm, initially at a volume of 1L per day, increasing to 1.5L based on the calves' body weights (10% of body weight in milk). Weaning can be accomplished by reducing milk feedings from twice daily to once daily, with calves being weaned at 60 days of age, during that, decreasing the milk intake to 0.5 liters seven to ten days before weaning.

Measurement of body weight and withers height

Before receiving colostrum feedings, calves were weighed in the study. Body weight (BW) and withers height (WH) were subsequently measured weekly until day 126, using a scale for body weight measurement and a measure tape for withers height. Cattle body weight is a crucial and commonly used factor in animal production that significantly affects feed intake, breeding potential, social behavior, and overall farm management.

Experimental Diets and Feeding

The concentrate diet used consists of wheat, barley, yellow corn, soybean meal, vitamin, salt, and minerals, while wheat straw was available as a basal diet (Table1). Food was offered twice a day at 9 am and 4 pm to support maintenance and daily gain.

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Ingredient as DM % basis	Percentage's participation
Corn grain	25.0
Wheat grain	19.8
Barely grain	16.0
Soybean meal (44%)	20.2
Wheat bran	11.0
Limestone	2.1
Salt	1.6
Vitamins and minerals	1.6
Sodium bicarbonate	1.4
Toxin binder	1.3
***Chemical composition%**	
Dry matter	91.1
Crude protein	19.1
Metabolizable energy (Mcal /kg DM)	2.96
Natural detergent Fiber	16.0
Acid detergent fiber	6.6
Fat	2.7
Ash	10.2
Calcium	0.95
Phosphors	0.49
*The chemical composition of the experimental diet was calculated according to the NRC, 2001.	

Table (1): Formulation and chemical composition of experimental diet

Blood sample collection and analysis

A 10mL disposable syringe with a 22-gauge hypodermic needle and a non-vacuum EDTA K3 blood collection tube was used to measure hematocrit, which includes white blood cells (WBC), eosinophils (ESO), lymphocytes (LYM), monocytes (MON), basophils (BAS), and neutrophils (NEU) by (Orphee mythic-22 5-part differentiation). Blood was taken approximately an hour after a morning meal, centrifuged for 10 minutes at 4°C at 3000×rpm to extract the serum, aliquoted, and stored at -20°C until analysis time using the ELISA Kit (Cattle PRL "prolactin," cat: ELK8218, ELK Biotechnology) and the BioTek Microplate Reader ELX800 and BioTek Microplate Strip Washer ELX50.

Health care

Eye discharge, ear disposition, nasal discharge, coughing, and fecal score were measured twice a week using a standardized scoring method. A score of 0 denotes normal, while a score of 3 denotes significant abnormality.

Statistical analysis

Using SAS (2016) PROC GLM (version 9.4; SAS Institute Inc., Cary, NC), least squares ANOVA was applied to evaluate body weight, wither height, health care components (eye score, ear score, nasal discharge, cough, and fecal score), and five differential total for WBC. The cow was regarded as a variable at random, and treatment was example of fixed effects. Least squares mean ± standard error of the mean is used to display the data. A 5% chance (P<0.10) was employed to assess propensity.

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III. Result and Discussion

Body weight

Table 2 shows the body weight (Mean ± S.E., kg) of calves raised in individual, pair, and group housing systems from birth to eighteen weeks. There were no variations in body weight across treatments at birth, suggesting that the starting circumstances were identical. In all treatments, body weight gradually rose with age.

Body weights were comparable among the individual, pair, and group treatments from birth to week six. Animals raised in group and pair housing, however, showed greater body weights than those raised separately starting in week 8. From week 11 to week 18, there were statistically significant differences (P<0.05) between treatments (Table 2).

While pair-reared calves displayed intermediate values and did not substantially vary from either group or individual treatments, group-reared animals had significantly higher body weights at weeks 11, 12, 16, and 18. Animals in the group treatment had the maximum body weight by week 18 (50.50 ± 2.69 kg), followed by those in pair housing (47.08 ± 2.20 kg) and individual housing (42.30 ± 2.40 kg) (Table 2).

The results of the research show that the housing system significantly affects growth performance, especially in later phases of development. The absence of treatment differences in the early stages of life indicates that social housing has little effect on development right after birth, however as animals become more mature, the consequences become more noticeable (Miller-Cushon and DeVries, 2016).

Compared to individual households, group housing produced greater body weight growth, most likely as a result of better food practices, less stress, and increased social engagement. It has been demonstrated that social facilitation in group settings improves feed intake and development efficiency in developing animals (de Paula Vieira *et al*., 2010). Individual housing, on the opposite side, may lead to social stress, which may have negative effects on development performance (Duve and Jensen, 2012).

Pair housing elicited moderate growth responses, suggesting that restricted social interaction might somewhat alleviate the adverse consequences linked to individual upbringing, while it does not quite match the advantages of group living. These findings support the implementation of group housing methods to enhance growth performance and animal wellbeing.

Table (2). The body weight of calves during different times among their life

Treatment / Time	Individual Body weight ± S.E. kg	Pair Body weight ± S.E. kg	Group Body weight ± S.E. kg
At birth	18.70 ± 1.54	18.33 ± 1.41	18.25 ± 1.73
Week 2	19.20 ± 2.26	19.50 ± 2.07	18.75 ± 2.53
Week 4	22.60 ± 2.50	22.75 ± 2.28	22.63 ± 2.80
Week 6	25.30 ± 2.48	26.92 ± 2.26	27.25 ± 2.77
Week 8	26.80 ± 1.77	29.33 ± 1.61	30.13 ± 1.98
Week 10	28.90 ± 1.49	32.67 ± 1.36	33.63 ± 1.67
Week 11	29.80 ± 1.60 [a]	33.92 ± 1.46 [ab]	36.0 ± 1.79 [b]
Week 12	31.0 ± 1.66 [a]	35.17 ± 1.51 [ab]	37.13 ± 1.85 [b]

Week 14	34.40 ± 2.09	38.17 ± 1.91	40.63 ± 2.34
Week 16	38.0 ± 2.17 [a]	42.17 ± 1.98 [ab]	45.13 ± 2.43 [b]
Week 18	42.30 ± 2.40 [a]	47.08 ± 2.20 [ab]	50.50 ± 2.69 [b]

Table 1. Body weight (Mean ± S.E., kg) of animals reared under individual, pair, and group housing systems from birth to 18 weeks. Different superscript letters within a row indicate significant differences among treatments (*P*<0.05).

Withers height

The withers height (Mean ± S.E., cm) of animals raised in individual, pair, and group housing systems from birth to 18 weeks is presented in table 3. At birth, no significant differences in withers height were noted among treatments, indicating uniform skeletal size at the experiment's onset. The withers height consistently rose with age across all housing schemes.

From birth to week 8, withers height shown no significant differences across individual, pair, and group treatments. Significant differences (*P*<0.05) among treatments showed from week 11 onwards. Throughout this period, animals raised in pairs and group housing demonstrated increased withers height in comparison to those kept individually (Table 3).

During weeks 11 to 18, pair-raised animals consistently exhibited the greatest withers height, followed by group-reared animals, whereas individually reared animals had the lowest measurements. Pair housing shown significant differences from individual housing at all time periods, whereas group housing often had intermediate values and did not significantly differ from pair housing at certain ages. At week 18, withers height measured 77.83 ± 0.95 cm in pair-raised animals, 76.75 ± 1.17 cm in group-reared animals, and 74.00 ± 1.05 cm in individually reared animals (Table 3).

The results show that the housing system significantly affects skeletal growth, as seen by withers height, especially in the later phases of development. The absence of treatment differences in early growth indicates that housing circumstances have little impacts on skeletal development immediately post-birth; nevertheless, these effects intensify as the animals mature (AlKudsi and Elia, 2010).

Pair and group housing facilitated a bigger withers height in comparison to individual housing, presumably due to enhanced physical activity, social engagement, and lower stress levels. Augmented mobility and social engagement in pairs and groups may facilitate enhanced bone formation and total skeletal growth. Animals kept individually consistently demonstrated reduced withers height, potentially linked to limited mobility and social isolation (Neave *et al*., 2018).

Pair housing produced the highest withers height over the majority of the later growth phase, indicating that restricted social grouping may offer an ideal equilibrium between social engagement and less resource rivalry. Group housing had similar yet somewhat reduced prices, either attributable to heightened competition or the influence of social hierarchy. These findings indicate that social housing systems, especially pair housing, beneficially affect skeletal growth and should be taken into account when refining management procedures for developing animals.

Table (3). The withers height of calves during different times among their life

Treatment / Time	Individual Withers height ± S.E. cm	Pair Withers height ± S.E. cm	Group Withers height ± S.E. cm
At birth	61.20 ± 1.16	62.33 ± 1.05	62.0 ± 1.29
Week 2	62.60 ± 1.16	64.33 ± 1.06	63.0 ± 1.30
Week 4	64.40 ± 1.10	66.33 ± 1.00	66.0 ± 1.23
Week 6	65.80 ± 1.17	67.50 ± 1.07	67.0 ± 1.31

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Week 8	67.0 ± 1.05	69.17 ± 0.96	68.75 ± 1.17
Week 11	68.40 ± 1.06 [a]	71.83 ± 0.96 [b]	71.75 ± 1.18 [ab]
Week 12	69.0 ± 1.17 [a]	72.50 ± 1.07 [b]	72.25 ± 1.31 [ab]
Week 13	69.60 ± 1.02 [a]	73.83 ± 0.93 [b]	73.0 ± 1.14 [b]
Week 14	69.80 ± 1.10 [a]	74.50 ± 1.01 [b]	73.75 ± 1.23 [b]
Week 15	70.60 ± 1.10 [a]	75.17 ± 1.01 [b]	74.75 ± 1.23 [b]
Week 16	72.40 ± 1.13 [a]	75.83 ± 1.03 [b]	75.25 ± 1.26 [ab]
Week 17	73.0 ± 1.12 [a]	77.0 ± 1.02 [b]	76.25 ± 1.25 [ab]
Week 18	74.0 ± 1.05 [a]	77.83 ± 0.95 [b]	76.75 ± 1.17 [ab]

Table 2. Withers height (mean ± S.E., cm) of animals reared under individual, pair, and group housing systems from birth to 18 weeks. Different superscript letters within a row indicate significant differences among treatments ($P<0.05$).

Health parameter

Clinical health parameters were generally low across all treatments throughout the study period (weeks 1–8).

Cough and nasal discharge scores were minimal and brief. Mild coughing was noted exclusively in the individual treatment during weeks 1 and 5, but the pair and group treatments exhibited no coughing at any time point. Nasal discharge had a comparable trend, with minimal scores at weeks 1 and 5 and complete resolution by week 3 across all treatments (table 4).

Ear and eye scores consistently approached 0 across all treatments. The group housing exhibited marginally heightened ear and eye scores throughout weeks 1–5; yet, these increments were minimal and subsided by week 8. The individual and pair treatments exhibited negligible or no anomalies throughout the investigation (table 4).

Fecal scores demonstrated the most significant treatment-related variations. During week 3 (at the beginning and midpoint), the group treatment exhibited substantially elevated fecal scores (0.50 ± 0.14) in comparison to the individual and pair treatments (both 0 ± 0; $P<0.05$). At week 8, the individual treatment exhibited a markedly superior fecal score (0.80 ± 0.20) in comparison to the group treatment (0 ± 0.22), but the pair treatment yielded an intermediate value (0.50 ± 0.18) (table 4).

The current research shows that housing circumstances exerted minimal influence on respiratory, eye, and nasal health metrics, however gastrointestinal responses, shown by fecal scores, exhibited greater sensitivity to treatment variations over time. In general, clinical manifestations across all treatments were modest, transitory, and within acceptable physiological limits, suggesting that the animals acclimated effectively to their particular housing environments.

Respiratory characteristics, such as cough and nasal discharge, were minimal throughout the research. The transient moderate coughing and nasal discharge observed in the individual treatment during the early and mid-study phases may indicate short-term adaption stress; however, the swift recovery of these symptoms implies no enduring detriment to respiratory health. Previous research has shown analogous findings, indicating that minor respiratory symptoms during environmental changes are often temporary and self-limiting (Godden, 2008; Abdullah and Ahmed, 2023).

During weeks 1–5, eye and ear ratings were marginally higher in the group housing. Enhanced social interaction in communal dwelling may heighten the likelihood of mild ocular or aural discomfort due to proximity, increased dust exposure, or grooming-related contact (Almasri *et al*., 2020). The normalization of these scores by week 8 indicates effective acclimatization and corroborates prior findings that group-housed animals adjust over time as social hierarchies settle (Liu *et al.*, 2019).

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Fecal scores exhibited the most distinct and persistent treatment-related variations, suggesting that gastrointestinal health may be more susceptible to housing-related stresses. The markedly elevated fecal scores seen in the group housing at week 3 indicate a transient gastrointestinal reaction during the first stage of group formation. Social stress linked to the creation of hierarchy and competitiveness has been demonstrated to modify gut motility and microbiota composition, resulting in temporary soft stools or diarrhea (Bailey *et al.*, 2011; Cryan and Dinan, 2012).
Conversely, the individual treatment had markedly elevated fecal scores at week 8, indicating postponed gastrointestinal symptoms linked to extended social isolation. Chronic isolation is associated with dysregulation of the hypothalamic–pituitary–adrenal (HPA) axis, elevated corticosterone levels, and modified gut permeability, all of which may adversely impact intestinal function over time (Reber *et al.*, 2016; Overvest *et al.*, 2018). The intermediate fecal scores recorded in the pair treatment during the trial indicate that restricted social engagement may alleviate both initial social stress and prolonged isolation-related consequences.
Collectively, these data suggest that gastrointestinal indicators exhibit greater sensitivity to housing circumstances compared to respiratory or ophthalmic measurements. Group living may cause transient stress-induced gastrointestinal alterations, but individual housing may render animals susceptible to prolonged gut problems. Pair dwelling seems to provide a harmonious atmosphere, potentially mitigating both acute and chronic stress reactions.

Table (4). Health parameter of calves during different times among their life

Treatment / Time	Individual Mean ± S.E.	Pair Mean ± S.E.	Group Mean ± S.E.
Cough			
Week 1	0.20 ± 0.12	0 ± 0.11	0 ± 0.13
Week 3	0 ± 0	0 ± 0	0 ± 0
Week 5	0.40 ± 0.14	0 ± 0.13	0 ± 0.16
Week 8	0.20 ± 0.12	0 ± 0.11	0 ± 0.13
Ear score			
Week 1	0 ± 0	0 ± 0	0 ± 0
Week 3	0 ± 0.11	0 ± 0.10	0.25 ± 0.13
Week 5	0.20 ± 0.12	0 ± 0.11	0 ± 0.13
Week 8	0 ± 0	0 ± 0	0 ± 0
Eye score			
Week 1	0.20 ± 0.16	0 ± 0.15	0.25 ± 0.18
Week 3	0 ± 0.11	0 ± 0.10	0.25 ± 0.13
Week 5	0 ± 0.11	0 ± 0.10	0 .25 ± 0.13
Week 8	0 ± 0	0 ± 0	0 ± 0
Fecal score			
Week 1	0.40 ± 0.26	0.17 ± 0.24	0 ± 0.29
Week 3	0 ± 0.13 ^{a}	0 ± 0.12 ^{a}	0.50 ± 0.14 ^{b}
Week 5	0.40 ± 0.18	0 ± 0.16	0.25 ± 0.20
Week 8	0.80 ± 0.20 ^{a}	0.50 ± 0.18 ^{ab}	0 ± 0.22 ^{b}
Nasal discharge			
Week 1	0.20 ± 0.16	0 ± 0.15	0.25 ± 0.18
Week 3	0 ± 0	0 ± 0	0 ± 0

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Week 5	0.20 ± 0.16	0 ± 0.15	0 .25 ± 0.18
Week 8	0.40 ± 0.14	0 ± 0.13	0 ± 0.16

Different superscript letters within a row indicate significant differences among treatments (P<0.05).

White blood cells (WBC)

Total WBC counts differed among treatments at particular time periods. At month 1, pair-housed animals exhibited significantly elevated WBC counts (10.72 ± 0.45 $\times 10^9$/L) in comparison to the group treatment (9.05 ± 0.56 $\times 10^9$/L), while the individual treatment yielded intermediate results (9.20 ± 0.50 $\times 10^9$/L). No notable alterations were seen during month 2. During months 3 and 4, WBC levels were markedly elevated in the pair housing relative to the individual housing, whereas the group housing exhibited intermediate values (table 5).

Lymphocyte count (Lymph #)

The lymphocyte numbers exhibited a same pattern. At month 1, pair-housed animals had substantially elevated lymphocyte counts compared to group-housed animals, whereas individual values were intermediate. During months 2 to 3, lymphocyte counts were significantly elevated in the pair housing relative to the individual treatment (P<0.05), but group values were often intermediate. By the fourth month, the disparities across treatments ceased to be substantial (table 5).

Lymphocyte percentage (Lymph %)

No significant differences in lymphocyte percentages were seen among treatments at any time interval. The percentage of lymphocytes rose from month 2 to months 3 and 4 across all treatments, suggesting a general alteration in leukocyte distribution over time rather than a treatment-specific impact (table 5).

Granulocyte count (Gran #)

Granulocyte counts exhibited treatment-related variations during month 3. Pair-housed animals had markedly elevated granulocyte counts (3.67 ± 0.19 $\times 10^9$/L) in comparison to both individual and group treatments (2.80 ± 0.21 and 2.80 ± 0.23 $\times 10^9$/L, respectively). No notable alterations were seen at months 1, 2, or 4 (table 5).

Granulocyte percentage (Gran %)

At month 1, the group housing exhibited a considerably elevated granulocyte percentage in comparison to the pair treatment, whereas the individual treatment had intermediate values. No notable changes were seen in the subsequent months, and granulocyte percentages decreased across all treatments by months 3 and 4 (table 5).

Monocyte count (Mon #)

Monocyte numbers showing significant variation at months 3 and 4. Animals housed in pairs had elevated monocyte counts relative to those in individual treatment (P<0.05), but group-housed calves demonstrated intermediate values. No notable alterations were detected within the initial two months (table 5).

Monocyte percentage (Mon %)

The monocyte proportion remained consistent among treatments at the majority of time periods. At month 1, the Mon % values were comparable for individual (7.98 ± 0.44), pair (7.78 ± 0.40), and group (7.55 ± 0.49) treatments. A significant treatment impact was seen at month 2, with the individual treatment exhibiting a greater monocyte percentage (8.50 ± 0.33) than the pair treatment (7.40 ± 0.30), while the group treatment was intermediate (7.75 ± 0.37). No substantial changes were seen at months 3 or 4, but there was a general numerical rise in Mon % across all treatments (table 5).

Housing factors predominantly affected hematological profiles by altering absolute leukocyte numbers rather than causing enduring changes in leukocyte distribution. All measures stayed within normal physiological limits, suggesting adaptive immune regulation instead of pathogenic reactions.

Pair housing correlated with persistently elevated total WBC counts and increased absolute counts of lymphocytes, granulocytes, and monocytes, especially at later time intervals. This pattern indicates increased immune cell availability with moderate social contact, possibly due to less chronic stress and improved immunological homeostasis. Prior research indicates that balanced social situations enhance immune function by mitigating extended activation of stress-related neuroendocrine pathways (Sweeney *et al.*, 2009; Horvath and Miller-Cushon, 2018).

Individual housing led to reduced leukocyte counts at several time intervals and a temporary rise in monocyte percentage at month 2. Monocytes, being responsive to acute stress and inflammatory signals, presumably exhibit this transient increase as an initial immunological adaptation to stress (Sacta *et al.*, 2016). The lack of enduring alterations at subsequent time points indicates physiological adaptability despite ongoing individual housing.

Group housing often resulted in moderate leukocyte numbers. The increased granulocyte percentage noted at month 1 aligns with an acute stress response during the initial group setup, since granulocytes are swiftly recruited in response to short-term stress or inflammatory conditions (Mohri *et al*., 2007). Normalization at subsequent time periods signifies social stability and immunological adaptability.

The absence of enduring impacts on leukocyte percentages indicates a maintained leukocyte equilibrium throughout housing situations. The treatment effects were mostly shown by variations in total leukocyte availability, suggesting functional immunological modulation instead of immune dysregulation. The data indicate that pair living offers an optimal equilibrium between social contact and stress alleviation, whereas group and individual housing elicit temporary, adaptive immunological responses without causing enduring alterations in leukocyte composition.

Collectively, these data substantiate the notion that pair dwelling offers an advantageous equilibrium between social contact and stress alleviation, hence promoting more stable hematological profiles throughout time. Group living may provoke temporary immunological responses after first exposure, but individual housing may cause brief stress-related alterations without long-term changes in leukocyte composition.

Table (5). Hematological parameter of calves under different housing treatments over time

Treatment / Time	Individual Mean ± S.E.	Pair Mean ± S.E.	Group Mean ± S.E.
WBC $*10^9/L$			
month 1	9.20 ± 0.50 ^{ab}	10.72 ± 0.45 ^{b}	9.05 ± 0.56 ^{a}
month 2	10.48 ± 0.83	11.57 ± 0.76	11.48 ± 0.93
Month 3	8.06 ± 0.54 ^{a}	10.17 ± 0.49 ^{b}	8.53 ± 0.60 ^{ab}
Month 4	8.82 ± 0.50 ^{a}	10.42 ± 0.45 ^{b}	10.05 ± 0.55 ^{ab}
Lymph # $*10^9/L$			
Month 1	4.36 ± 0.39 ^{ab}	5.55 ± 0.35 ^{b}	3.98 ± 0.43 ^{a}
Month 2	4.52 ± 0.36 ^{a}	5.67 ± 0.33 ^{b}	5.08 ± 0.40 ^{ab}
Month 3	4.60 ± 0.25 ^{a}	5.62 ± 0.23 ^{b}	4.98 ± 0.28 ^{ab}
Month 4	5.02 ± 0.28	5.55 ± 0.26	5.15 ± 0.31
Lymph %			
Month 1	48.14 ± 3.06	51.12 ± 2.79	42.65 ± 3.42
Month 2	43.66 ± 2.67	49.75 ± 2.44	44.65 ± 2.98
Month 3	57.44 ± 2.76	54.77 ± 2.52	57.45 ± 3.08
Month 4	56.44 ± 2.77	54.07 ± 2.53	51.40 ± 3.10
Gran # $*10^9/L$			
Month 1	4.12 ± 0.31	4.33 ± 0.28	4.68 ± 0.35
Month 2	5.06 ± 0.42	5.07 ± 0.39	5.58 ± 0.48
Month 3	2.80 ± 0.21 ^{ab}	3.67 ± 0.19 ^{b}	2.80 ± 0.23 ^{a}
Month 4	3.10 ± 0.32	3.87 ± 0.30	4.0 ± 0.36
Gran %			
Month 1	43.88 ± 2.74 ^{ab}	41.10 ± 2.50 ^{a}	49.80 ± 3.07 ^{b}
Month 2	47.84 ± 2.50	42.85 ± 2.28	47.60 ± 2.79
Month 3	34.40 ± 2.52	36.30 ± 2.30	33.40 ± 2.82
Month 4	35.08 ± 2.62	36.10 ± 2.40	39.08 ± 2.93

Mon # *10^9/L			
Month 1	0.72 ± 0.06	0.83 ± 0.06	0.65 ± 0.07
Month 2	0.82 ± 0.09	0.83 ± 0.09	0.83 ± 0.10
Month 3	0.66 ± 0.06 ^{a}	0.88 ± 0.05 ^{b}	0.75 ± 0.07 ^{ab}
Month 4	0.70 ± 0.08 ^{a}	1.0 ± 0.07 ^{b}	0.90 ± 0.09 ^{ab}
Mon %			
Month 1	7.98 ± 0.44	7.78 ± 0.40	7.55 ± 0.49
Month 2	8.50 ± 0.33 ^{b}	7.40 ± 0.30 ^{a}	7.75 ± 0.37 ^{ab}
Month 3	8.16 ± 0.45	9.03 ± 0.41	9.15 ± 0.50
Month 4	8.50 ± 0.61	9.83 ± 0.56	9.53 ± 0.68

WBC, lymphocyte (Lymph #), granulocyte (Gran #), and monocyte (Mon #) counts are expressed as ×10^9/L. Lymphocyte (%), granulocyte (%), and monocyte (%) values represent relative proportions of total leukocytes. Values are presented as mean ± standard error (S.E.). Means within the same row with different superscript letters (a, b) differ significantly (P<0.05). Values sharing at least one common superscript letter (e.g., ab) are not significantly different. Absence of superscript letters indicates no significant treatment effect.

IV. Conclusion

In conclusion, each housing system facilitated normal physiological development; nonetheless, they provoked unique adaptive responses. Group housing facilitated enhanced body weight increase, pair housing fostered optimal skeletal development and immunological equilibrium. Evaluating performance, health, and welfare in conjunction, pair housing seems to provide the best equitable and welfare-oriented housing arrangement for Karadi calves during the preweaning phase. These findings offer essential baseline data for enhancing calf management methods in indigenous cattle systems and augment the sparse scientific understanding of Karadi calf productivity and wellbeing.

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V. References

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